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WITCHES' BROOM DISEASE OF CACAO.

Two Memoirs (1) on the witches' broom disease of cacao have recently been issued by the Mycology Department of the Imperial College of Tropical Agriculture. The first presents a detailed account of the life history, symptoms, morphology and etiology of the disease while the second records field observations and reviews in some detail the question of control.

Witches' broom disease of cacao, which is widespread and probably indigenous to South America, was first recorded in Trinidad in 1928. Since then it has rapidly become worse and is now regarded as one of the chief factors responsible for the gradual deterioration of cacao plantations in the island. Prior to 1928 a good deal of work on witches' broom from the mycological standpoint, had already been done, notably in Suriname, but no further progress was made in its study until it was discovered in Trinidad. Certain aspects of the disease have since been much more fully investigated and although no effective methods of direct control have been discovered so far, the information which has now been accumulated throws considerably more light on this very serious problem.

The disease is one that can only be spread by means of spores which develop in sporophores on dry brooms. Moreover, it only attacks young growing tissues. A detailed study of sporophore formation in two localities revealed that sporophores are never produced on green brooms and that they occur on dry ones only after a definite period has elapsed. It is the duration of this period which is of the greatest importance in any attempt to control the disease, because it indicates how often the brooms should be removed annually to keep the disease in check. Normally, brooms become dry five or six weeks after they are formed though this period may last ten weeks. After drying, the usual dormancy period before sporophore formation begins is five or six months, but this period is very variable and its length depends on climatic conditions. Once sporophore production starts it continues, except during the height of the dry season, as long as the broom remains on the tree. After the end of the second year, however, sporophore production becomes

(1) Baker, R. E. D. and Crowdy, S. H.—Studies in the Witches' Broom Disease of Cacao. Parts I & II —*Memoirs* Nos. 7 & 8; *Dept. of Mycology and Bacteriology, I.C.T.A.*, Price: 3s. *each.*

considerably reduced. Brooms which have fallen from the tree very seldom produce sporophores and unless left in heaps, soon disappear. Not all brooms produce sporophores but large brooms produce many more sporophores than small ones.

No positive statistical correlation could be established between rainfall and the production of sporophores although it is known that the most important factors which influence this are atmospheric humidity and rainfall. Even a short period at a low relative humidity will destroy the viability of spores. Sporophore production generally reaches a peak in the wet season, and almost ceases during the latter part of the dry season. An increase in rainfall usually causes increased sporophore production, but excessive rain may have a depressing effect. Ideal conditions for sporophore formation are short, dry periods, followed by heavy falls of rain.

Sporophore production is at its maximum from October to February, most of the spores being produced on brooms formed in the preceding period of November to February. In order to prevent this intense sporophore production, which is followed by a great development of brooms in January and February, the routine removal of brooms in April and October is recommended. If broom removal has been thoroughly carried out in October, brooms subsequently formed cannot produce a sporophore before the next wet season and can consequently be safely left until the main clearance in April. The data obtained suggested that a careful removal of brooms by the end of May would reduce the total number of sporophores present the next wet season by 75 or 80 per cent. and that if a second removal was made in October or November, sporophore formation should be almost completely eliminated. There is no need to bury or burn the brooms. All that is necessary is to throw them on the ground and as long as they are not piled up in heaps they will produce very few sporophores. The same holds good for diseased pods and shells.

Observations in the field on a plot of seventy-six trees over a period of three years revealed that there is considerable tree to tree variation in respect of susceptibility. Trees which produced many brooms in one year generally did so again during the following year and trees which produced only a few brooms one year tended to behave similarly in the following year. Several trees produced fewer brooms during the second year, and some trees which were exceptionally large and vigorous produced many brooms without any noticeable loss of vigour. Quite unexpectedly no substantial positive correlation was found between total flush and the total number of fan brooms per tree. This would suggest that there are very important factors besides flush affecting the variation in the number of fan brooms from tree to tree and it seems reasonable to assume that the most important of these factors is likely to be a difference in susceptibility to the production of such brooms. There was, on the other hand, a high positive correlation between the number of flowers produced and the number of cushion brooms per tree per year. This suggests that resistance can hardly be physiological (*i.e.* due to some inherent property of the plant cell) and is therefore more likely to be due to some form of disease avoidance on the part of the vegetative buds of certain trees. In areas, therefore, infested by witches' broom very freely flowering trees are highly unsuitable.

The seasonal variation in broom formation is very marked. It reaches a maximum in January or February and a minimum about June or July. It was also observed that the heavy flush which occurs at the beginning of the dry season, usually in February, is accompanied by many brooms, in spite of the fact that by this time sporophore production has fallen considerably and conditions are probably much too dry for any infection to take place. The explanation is that the infections which caused these brooms occurred during the previous December when sporophores were plentiful and conditions suitable for infection. Similarly, the first flush of the wet season occurs at a time when sporophores are plentiful and conditions apparently suitable for infection yet contains very few brooms. In this case the previous flush took place during the dry weather when sporophores are very rare and environmental conditions unsuitable for infection.

As already pointed out, no satisfactory method of direct control of the disease has been found. The position at present in regard to control is considered not at all promising or even hopeful for some years to come. Spraying and dusting would almost certainly be uneconomic. Modifications in agricultural methods as another form of control do not at present appear feasible and would require detailed field experiments before they could be recommended for general use. Complete cutting out of all brooms twice a year should be just as effective as more frequent removal, but if carried out very thoroughly, even this system is expensive. Some measure of positive control might be achieved by this method if it could be effected simultaneously over considerable areas or even on small areas that are sufficiently isolated from other cacao. Thorold (3), however, has already carried out experiments at River and Phillipine Estates, on areas of 25, 40 and 80 acres (already surrounded by other cacao) in which brooms were very carefully removed once or twice a year. The results showed that the disease was not controlled in these circumstances. It seems unlikely at the moment therefore that practicable methods of direct control by such means will be discovered. The only hope now lies in the production of immune or highly resistant varieties of cacao. The existence of such is already substantially proved although nothing is yet known about what constitutes the mecanism of resistance. Future work should therefore be concentrated on the testing of the resistance of these types of cacao with a view to their general cultivation in Trinidad.

(3) Thorold, C. A.—*Trop. Agriculture*, XX, No. 9, pp. 176-181.

COTTON GROWING IN THE WEST INDIES DURING THE 18th AND 19th CENTURIES

BY

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I. Introduction.

The history of the modern cotton growing industry in the West Indies begins in the year 1897 when a Royal Commission visited these islands. The visit was occasioned by the serious plight into which cane planting—for over two hundred years previously the principal occupation of the West Indian colonies—had fallen, owing to competition of the sugar beet industry on the continent of Europe. As a result of the Commission's recommendations, experiments in cotton growing were commenced in St. Lucia (1901) and later in St. Kitt's, Antigua, Montserrat and Barbados (1902). Of several strains tested, "Sea Island" cotton from the Carolinas proved most successful and the progenies of the original stocks have continued so until the present day.

Prior to 1900, cotton had not been grown in the West Indies on an appreciable scale for nearly a century, with one exception—the Grenadines where it had persisted under a primitive form of peasant cultivation which still survives. Apart from this, and the presence of semi-wild cottons throughout the West Indies, nothing but the most fragmentary data bridges the gap between present day, and former cultivations. Yet it is known that cotton growing in the West Indies goes back far beyond historical times, since the original inhabitants when discovered by Columbus (1) already understood the arts of cotton spinning and weaving. Long afterwards, at the end of the eighteenth century a level of production was reached which has never been surpassed in these islands. In 1770 according to Crawford (2) seventy per cent. of British cotton consumption (ten thousand bales) was obtained from the West Indies, and in 1801 twenty-five thousand bales were shipped to Europe (3).

The paucity of reliable information which is available can be readily understood. Cotton growing in the Western Hemisphere did not expand appreciably until the machines of Arkwright, Hargreaves and Crompton created a vastly increased demand. Secondly, the intense competition between Spanish, Dutch, French and English in securing colonies was not an atmosphere in which a settled agriculture and the keeping of accurate records could easily develop. The colonists of the eighteenth century still had to contend not only with disease, war-like Indians, and shortage of labour for clearing new territories, but also with the constant danger of conquest by rival European forces against whom they were but inadequately furnished with means of defence. Nevertheless, it is probable that a careful search through ancient records and historical documents would yield information of the greatest interest, both from the botanical and agricultural points of view. The purpose of this paper is to bring together data relevant to cultivation of cotton in the West Indies in the 18th and 19th centuries which occur for the most part in the collection of the Historical Society of Trinidad and Tobago. The information obtained probably represents only a fraction of the data available from similar sources, but it would seem worth while to place on record what may provide a nucleus for further research. I have been greatly indebted to Mrs. Carmichael, Assistant Librarian at the Imperial College of Tropical Agriculture and Hon. Librarian of the Historical Society of Trinidad and Tobago for suggestions and guidance in searching through the records.

II. The growth and decline of cotton cultivation in the West Indies

Although cotton was found growing in the West Indies in some abundance by the early Spanish settlers in the 16th century, it does not appear to have attracted much attention for the next 100 years. In 1597, Antonio de Berrio, responsible for the following description (4) of its agricultural possibilities:

> "It is a land very abundant in yucca, maize and sugar cane. The undergrowth is of plantain, there are plenty of potatoes, a great quantity of cotton . . . . ."

Yet forty years later (1637) Jacques Ousiel, Secretary of Tobago under the Dutch West India Company found nothing cultivated in Trinidad in any quantity except tobacco which was collected by a ship sent annually from Spain (5). In 1632 Antigua was settled by the English, who grew tobacco as the first crop (6). In Barbados in 1657 according to Richard Ligon's "History", tobacco, sugar, ginger, indigo, cotton-wool and fustic wood were produced for export (7) but it is clear from the attention devoted to it that sugar was easily the most important crop. A prospectus for settlers in Tobago issued in England in 1686 (8) reviewed the prospects of success in tobacco and cacao growing but made no mention of cane or cotton. These and other data show that tobacco and, later, sugar and indigo were the principal West Indian products until the end of the 17th century.

The first indication of an awakening interest in cotton in the West Indies is probably the record by Carroll, cited Watt (9), of colonists from Barbados settling in America at Cape Fear

in 1664 and bringing cotton seed with them. By 1683, at the latest, different sorts of cotton were recognised. A prospectus of Tobago (10) published at that date contains the following passage:

> "There are two sorts of Cotton, Ravil and Vine, of either sort of which an industrious Planter may plant two thousand weight in a year and this I look upon as the meanest staple in Tobago for a man to go upon"

Sir Hans Sloane (1725) in his "Natural History of Jamaica" gives an illustration of a roller gin, and the interest of European countries in the possibility of growing cotton in North American colonies and the West Indies was fully aroused when Philip Miller's "green seeded" cotton was introduced into Georgia in 1734. This green seeded type which seems to have been a forerunner of American Upland cottons (*G. hirsutum* L.) was immediately recognised, according to Watt (9), "as an immensely superior stock to the Levantine plant, previously grown."

In spite of the developing cotton industry in the West Indies, sugar continued to hold the chief attention of planters during the early half of the 18th century. Then circumstances arose both in England and the West Indies which for fifty years were to bring cotton to the forefront in colonial agriculture. By 1776 the invention of spinning machinery in England had created a vastly increased demand for the raw material. At the same time cane planting throughout the West Indies received a severe check with the sudden appearance in enormous numbers of a Sugar Ant* which devastated the crop. This pest seems to have made its first appearance in the French islands and by 1775 the island of Martinique was so over-run with ants that the inhabitants offered "a reward of a million livres in Martinique currency to any person of whatever nation who shall effectively extirpate them." Rewards of £20,000 and £5,000 were offered by Grenada and Tobago respectively (11, 12) for similar services. Edwards (6) states that the ants were not of the leaf cutting variety, the damage being caused by their building nests under the roots of the cane so that "they became sickly and stinted". He describes them as being "of a middle size, of a slender make and of a dark red colour" and states that "when rubbed together between the palms of the hands, they emitted a strong vitriolic sulphurous smell". An idea of their numbers is given by his description:

> ". . . . . So crowded were they in many places that the prints of the horse's feet would appear for a moment or two until filled up by the surrounding multitude"

The ants did not nest in the comparatively open root systems of cotton plants and this fact together with the increasing demand for cotton was sufficient to bring about a change-over† to that crop (13).

The rapid switch from cane to cotton growing is well illustrated by the figures obtained from the Official Census of Tobago (14) which are given in the Table. Cotton first appears in the census in 1780 and from then onwards until 1790 it retains its importance while sugar gradually declines. A comparison of acreages and yields of the two crops does not, however, give a complete picture of their relative importance. In 1788 the inhabitants of Tobago, then under French Government, were fined a sum of

* *Formica omnivora* L. according to Schomberg's "History of Barbados".

† Although not stated by Edwards, it would seem likely that the cultivation entailed in changing from cane to cotton was a potent factor in destroying the ants.

TABLE:—Relative production of Cotton and Sugar in Tobago 1772-1790

	Year	Acreage			Yield		Factories		
		Sugar	Cotton	Provisions	Sugar (lbs.)	Cotton (lbs.)	Sugar	Cotton	Both
English	1772	2815	—	—	3589200	—	—	—	—
	1773	4457	—	—	—	—	41	—	—
	1780	—	—	—	3934830	1518220	—	—	—
French	1782	16131		3804	2132100	95400	37	80	25
	1785	4241	13643	3877	1750212	1227100	38	107	—
	1786	3458	15699	3769	1300248	1220570	35	113	—
	1787	2747	16874	4180	1250788	1431600	32	114	—
	1788	2941	16320	3845	1212400	1077700	31	120	—
	1790	4878	14436	4842	2401639	1374336	37	99	—

240,000 livres by the King of France. A tax was levied on the produce of the island in order to pay off the fine (15). The two principal items taxed were cotton and sugar:

12 livres per quintal of cotton	177,237 livres
1 livre 13 sols per quintal of Muscovado sugar	40,021 ,,

It is clear from these figures that cotton was easily the most profitable crop at the time since over half the total tax was raised from it.

The pre-eminence of the West Indies in producing cotton for European markets lasted until the turn of the century and at first it received no serious challenge from the Southern States of America. One of the chief limitations to expansion of cotton exports in the latter country was the type of cotton grown, *viz.*, the green seeded variety. Owing to its densely fuzzy seeds the lint could not be successfully removed by the roller gins then available but had to be removed by hand. On the other hand the naked and tufted seeded varieties grown in the West Indies (Shrub cottons) could be readily de-linted by roller gins. This advantage however disappeared when Whitney patented the saw-gin in 1793 and from that date onwards American cotton production soared. Johnson (16) gives the following figures:

Year	*U.S.A. cotton production in 500 lb. bales*
1793 (Saw-gin patented)	6,000
1795	20,000
1800	96,000

The rapid increase in American production had serious repercussions on the West Indian cotton trade. By 1800 West Indian cotton production had passed its peak, and cane and cocoa gained the ascendancy. In 1801 twenty-five thousand bales of cotton were shipped from the West Indies and by 1836 this figure had fallen to twenty thousand (3). From then onwards cotton production rapidly diminished except for a short renewal during the American Civil War (1863-5) when cotton exports to Europe from the States were temporarily suspended. Only in the Grenadines did cotton growing persist into the twentieth century.

This rapid development of cotton growing at the end of the 18th, and its decline in the 19th century is clearly reflected in the historical records of the individual West Indian colonies during this period. According to Edwards (6) Jamaica in 1768 exported 492,600 lbs. of cotton, Grenada in 1776, 91,943 lbs. By 1788 cotton production had expanded considerably. Edwards gives the following figures for cotton exports during the season 1787-8:—

	Cotton exports (lbs.)
*Grenada	2,062,427
Jamaica	1,906,467
Barbados	1,894,365
Virgin Islands	1,026,699
†Tobago	1,077,700
Dominica	970,816
St. Vincent	761,880
St. Kitts	484,640
Antigua	160,510
Montserrat and Nevis	92,472

It is interesting to note that the principal cotton islands of to-day, St. Vincent and Montserrat, were well down the list, though it should be borne in mind that the exports from Jamaica and Grenada included produce from neighbouring islands brought in under the Free Port Acts. However, only 10 per cent. of Jamaica's cotton exports came from outside the colony in 1787-8 (6) and it is unlikely that Grenada's re-exports were considerable since its Free Port Act was only introduced in the same year. In Barbados during the period 1788-92, cotton exports fell from 1,894,365 lbs. to 974,178 lbs. while sugar increased from 10,309 hogsheads to 17,073 hogsheads. Edwards notes that the great increase in sugar corresponding to decreased cotton exports was due to increased sugar prices in Europe which "encouraged the cultivation of that article on Plantations which had formerly been abandoned or appropriated to a different line of culture". In British Guiana (17) cotton cultivation was commenced in 1752 and by 1803 46,435 bales were exported; a figure which had fallen to 9,587 bales in 1823. The decline was due to a switch over to sugar and coffee growing, very little cotton being produced after 1838.

One of the more complete accounts of cotton growing during the productive years is available in old Trinidad records. Under Spanish rule the development of this island appears to have lagged behind the rest of the Antilles until the last Spanish Governor, Don José Maria Chacon, offered every encouragement to settlers from neighbouring islands irrespective of race or nationality. The result was highly beneficial to Trinidad agriculture, since by 1777 French, English and American adventurers had begun to settle there, bringing with them negroes to cultivate the land. This policy was, however, a great grievance to inhabitants of the other islands, since Trinidad became a haven for political refugees, rogues of every description, and also escaped slaves who thereby obtained their freedom (18). At this time only the west coast in the neighbourhood of St. Joseph appears to have been settled by the Spaniards (19, 20) although the prospects for would-be planters were very good:—

> "As for produce, this can be sold on the spot or sent to Spain . . . . . Indigo grows splendidly, sugar canes ratoon ten years in succession without being replanted, coffee yields better than any other part of America, cotton produces up to four pounds when

* One million lbs. of which were contributed by Carriacou "in seasonable years".

† Taken from Table (p. 24); not Edwards' figures.

planted at nine by nine feet; tobacco yields a quartern to each foot while for cacao the lands are very good." (From a report from an adventurer in Trinidad to a French gentleman in Grenada (20)).

In 1787 a Free Port Act came into force in Grenada and as a result large tracts of land in Trinidad were put into cotton, the produce being marketed in Grenada in exchange for "provisions, dry goods, and hardware of British manufacture". In 1788 the Trinidad crop consisted mostly of cotton amounting in value to "300,000 pieces of eight" (21, 22). In 1796 according to de Verteuil (23) there were 103 cotton estates in Trinidad as compared with 159 sugar, 130 coffee, and 60 cacao estates. A letter from Sir Thomas Picton, Governor of Trinidad in 1802 (24), shows clearly that at that time cotton was second in importance to sugar. "Cotton" he says "can be only cultivated advantageously on the windward part of the island, the plant requiring in this country an exposure to the sea air". Nevertheless cotton increased in importance during the next decade, before giving way to sugar. The text figure, compiled from de Verteuil's book (23) and old records of exports in the "Trinidad Almanac" (25), gives an adequate picture of the growth and subsequent decline in cotton production. By 1835 cotton production had become almost insignificant. A return of produce and stock for the island in that year gives only 48 acres devoted to cotton out of a total of 66,785 acres under cultivation (of which 27,905 acres were in sugar). The cotton was restricted to two districts:—

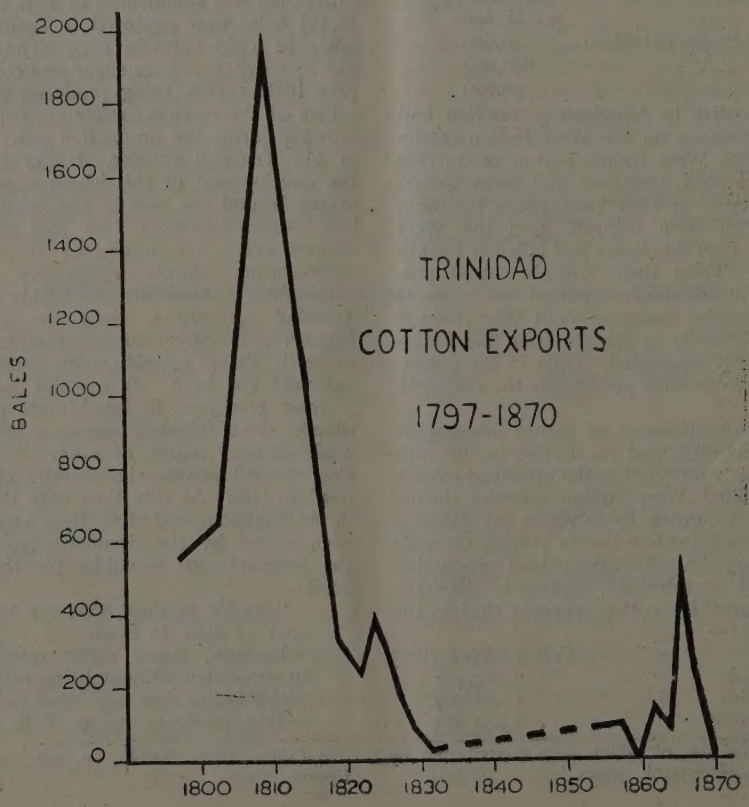
	Acres	*Yield (lbs.)*
Bocas	32	1,500
Mayaro	16	1,800
	48	3,300

As shown in the text figure the life of the crop was prolonged by the American civil war in 1863-5 but by 1875 it had disappeared finally from the list of principal exports in the "Trinidad Almanac".

III. The types of cotton grown

According to Hutchinson's recent classification (26), the cottons found in the West Indies to-day belong to two varieties of each of two species:—

(*a*) *G. hirsutum* var. *marie galante* } Free
(*b*) var. *punctatum* } seeded
(*c*) *G. barbadense* (type) } types
(*d*) var. *brasiliense* Kidney type



Of these (*a*) is by far the most common. It is found throughout the Lesser Antilles extending into the Greater Antilles as far as Cuba (26). It occurs wild, as in Jamaica (26), or semi-wild, as in Trinidad (27), and under mixed cultivation with *barbadense* in the Grenadines. Although (*b*) is the typical cotton of the Central American mainland bordering the Gulf of Mexico to the north and west, it does not penetrate far into the West Indies. It is found however in Cuba, Haiti, the Caymans and the Bahamas. The *barbadense* types (*c*) and (*d*) are common throughout the West Indies (*c*) including free seeded perennial types and the recently introduced annual fine linted Sea Islands, and (*d*) being represented by "kidney" cottons, *i.e.* with conglomerated seeds. Apart from the Sea Islands (annual forms of *G. barbadense*), cottons of the West Indies are all perennial types, and since no sharp distinction can be drawn between wild, semi-wild and types still grown commercially in the Grenadines, it seems reasonable to suppose that they represent relics of former cultivations. Nevertheless, this supposition is very difficult to establish critically. From the data available in old records it has only been possible so far to state with certainty that perennial kidney and free-seeded cottons were cultivated and that annual cottons were unknown. Although detailed descriptions of cottons are infrequent in old records, it is not their rarity, so much as the intrinsic difficulty of differentiating cotton species by purely morphological studies, that offers an obstacle to recognition. The early travellers in the West Indian colonies described the most striking characters of cotton rather than distinctions between different cottons, and even later botanists, *e.g.* Watt (9) based their classifications to a large extent on morphological differences shown by herbarium specimens. On the other hand the modern classification depends also on the results of genetic, geographical and cytological studies of living material. It is then found that certain morphological differences such as yellow or cream petals, with or without a petal spot; fuzzy, naked or tufted seeds; broad or laciniated leaves; hairy or glabrous plant body; can occur as parallel variations within either of the species *G. hirsustum* or *G. barbadense*, and therefore have little diagnostic value.

That the types cultivated prior to 1900 were, without exception, perennials, is clear from all available descriptions and records of the systems of cultivation. De Rochefort (28) describes cotton of the Antilles in 1645 as growing to the height of a small peach tree and called by the savages "Manoulou-Akecha". Cayenne cotton in 1743 is described as "Coton Arbrisseau" by Bellin (29). The system of cultivation varied little from that still employed in the Grenadines. Dry season planting appears to have been the rule, though both wet and dry season plantings were common in Jamaica. The cotton plants were thinned to a distance of 5 to 9 feet, often interplanted with corn or pulse, and pruned when they reached a height of 4 to 6 feet. Two crops were taken each year and the plants were ratooned annually, usually for three years or longer. The seed cotton was roller ginned for export (general references: 6a, 30, 31, 32).

One of the few morphological characters which by itself furnishes a valuable criterion for classification is the kidney seeded habit of *G. barbadense* var. *brasiliense*. This striking character was naturally described by the early travellers and botanists so that trustworthy data are available of its introduction and cultivation in the West Indies. It was first recorded by Jean de Lery, cited Lewton (33), in Brazil in 1557 and was brought to Jamaica from Brazil in 1594 (Sloane cited Lewton). In 1743 Bellin (29) described Surinam cotton bolls as having "three parts each containing a black seed to which the cotton is attached"—thus probably a kidney cotton. Long (31) describes it as the cotton of Jamaica in 1774 (*Gossypium seminibus majoribus Brasilianum*) and Edwards (6a) lists it as Kidney or Chain cotton in his classification (1793). Since independent studies of geographical distribution suggest Brazil as the centre of origin of kidney cottons it seems beyond doubt that the wild and semi-wild kidney types found in the West Indies to-day represent relics of formerly cultivated introduced types.

On the other hand the free-seeded types grown cannot be assigned to their correct species with any comparable degree of certainty. As far as present evidence goes, it appears that the earliest description of West Indian cottons is that given by De Rochefort (28) in 1645. He describes a tree form "Manoulou-Akecha" and another kind which "sprawls on the ground like a vine when unsupported", the latter producing "the finest and most esteemed cotton". Later, the named varieties "Ravil" and "Vine" are mentioned by Poyntz (10) in his prospectus of Tobago in 1683. These names occur again almost a century later (1750) in Hughes' "Natural History of Barbados" (30):—

> "Though the cotton wool is distinguished into the great, the Ravellin, the Vine, and Flying Fish sort, yet the trees bearing this variety of wool differ little from one another. The leaves of each are scalloped, of those bearing the great sort very deeply, not ill-resembling a Curran-Tree-Leaf in England. Those of the Flying Fish cotton-tree are likewise deeply segmented; having their middle and transverse ribs of a reddish colour. The leaves of the Ravellin and Vine are less scalloped and more blunt pointed . . . . . The flowers are composed of five large yellow leaves each stained at the bottom with a purple spot . . . . . the seeds . . . . . are blackish and small".

It seems clear from the above that the Ravellin and Vine were old established types which had been well known throughout the West Indies for over a century, but the descriptions given are of little value for determining their botanical

status. All the characters mentioned are well within the range of *G. hirsutum* var. *marie galante* which is the most frequent perennial cotton in the West Indies to-day, but the possibility that the narrower leaved types described belonged to *G. barbadense* cannot be ruled out (34).

There is some evidence that the cotton grown in the colonies belonging to France or under French influence was of higher quality than that grown in the British colonies. Bellin (29) states that the Tree-cotton grown in Cayenne in 1743 was "infinitely better and finer than that of the islands (Antilles) although it may be the same species that is cultivated everywhere . . . . . ". Edwards (6a) in classifying cottons of the West Indies says that the "French" or "small seeded" type was the cotton in general cultivation in Hispaniola (*i.e.* including the French colony of Haiti and Spanish San Domingo) and had a finer staple than the other cottons grown. Relative values are given as follows:—

	Per lb.		*Per lb.*
Berbice	2s. 1d.	San Domingo	1s. 10d.
Surinam	2s. 0d.	Tobago	1s. 9d.
Cayenne	2s. 0d.	Jamaica	1s. 7d.
Demerara	1s. 11d.		

The comparatively low prices in the British Islands were attributed by Edwards to the common practice of growing the French type with "inferior species". Ten years before Edwards' book was written, Tobago was captured by the French and was in French hands from 1781-1795. During the French occupation there is a record (35) of the excellent quality of its cotton:—

> "in the year 1792, Mr. Jonathan Pollard of Manchester succeeded in spinning yarn upon the mule of the fineness of 278 hanks to the pound from cotton wool grown by Mr. Robley in the island of Tobago. This yarn was sold at 20 guineas per pound to the muslin manufacturers at Glasgow . . . . . The cotton of the finest quality ever brought to the English market, or probably ever grown was that formerly mentioned, as having been raised in the island of Tobago between the years of 1789-92 upon the estate of Mr. Robley . . . . . "

It seems possible that this high quality cotton may have been introduced during the French occupation, and that the low price given by Edwards (above) refers to cotton growing prior to the French capture of the island.

The botanical problem which still cannot be settled critically is whether the French high quality cotton was a different species or merely a superior selection. Watt's classification (9) of New World cottons throws very little light on the problem. His interpretations of the types recognised by Edwards are presented below:—

Edwards	*Watt*
Green-seeded cotton	
(1) Fuzzy	*G. peruvianum* Cav.
(2) Semi-fuzzy	*G. peruvianum* Cav.
Shrub cotton	
(1) Common Jamaica (naked seeds)	—
(2) Brown Bearded (Tufted seeds)	
(*a*) White linted	*G. purpurascens* Poir.
(*b*) Khaki linted (Nankeen)	*G. purpurascens* Poir.
(3) French or Small-seeded (White-tufted seeds)	(?) *G. vitifolium* Lamk.
(4) Kidney or chain	*G. brasiliense* Macf.

These interpretations are, on the whole, dubious. If Watt's identification of Edwards' Green-seeded cotton with *G. peruvianum* (≡*G. barbadense*) is correct, it is rather surprising that to-day fuzzy-seeded *barbadense* cottons are not common in the West Indies. Out of 10 West Indian *barbadense* cottons in the Cotton Station collection only 2 are fuzzy-seeded and these are both Trinidad types. On the other hand, in *G. hirsutum* var. *marie galante*, fuzzy-seeded are at least as common as tufted and naked-seeded types, and in the majority of cases the fuzz is green in colour. Edwards' Brown Bearded type corresponds very well to the tufted *marie galante* cottons which are found throughout the West Indies and particularly in the Grenadines, so here Watt's classification as *G. purpurascens* (included in *G. hirsutum* var. *marie galante* Hutchinson) is not in question. The Common Jamaica type was not assigned to any botanical species by Watt. According to Edwards' description it was a naked coarse-linted type, *usually grown in mixed cultivation with the Brown Bearded.* It seems possible that it may have been a *barbadense* type since a coarse-linted, naked-seeded *barbadense* is still grown with good quality brown-tufted *marie galante* types in the Grenadines. This would agree with the hypothesis that the present Grenadine cultivation represents a relic of a formerly widespread system, but since coarse-linted *marie galante* types also occur in the West Indies the evidence is not critical. Although not specifically stated, Watt's description and geographical distribution of *G. vitifolium* (included in *G. barbadense* L. (Hutchinson)) coincides closely with that of Edwards' French or Small-seeded cotton. But if this interpretation is correct it must be concluded that the type is no longer represented in the West Indies, because present-day West Indian perennial *barbadense* cottons have distinctly *larger* seeds than *marie galante* cottons and they are invariably coarse-linted. Alternatively the French type may have been merely a superior selection of *marie galante*—a possibility conceded by Bellin (29). This is the more likely alternative since a unit of classification corresponding with *G. hirsutum* var. *marie galante* was never visualized by Watt and he distributed its members in what to-day seems an arbitrary manner among his other units; *punctatum purpurascens*, and *vitifolium*. Mr. Hutchinson informs me that the finest linted *marie galante*

types to-day are those found in the Grenadines. They are known locally as "Marie Galante" cottons, possibly named so after the French island from which they originated. As stated elsewhere, Watt's identification of Edwards' Kidney cotton with *G. brasiliense* (≡*G. barbadense* var. *brasiliense* Hutchinson) is not in question.

The general conclusion to be drawn from these studies is that there is no reason to suppose that perennial cottons found in the West Indies to-day differ from those cultivated in the 18th and 19th centuries. There is a strong possibility that *G. hirsutum* var. *marie galante* formed the major constituent of the crops, particularly in those colonies which produced high quality cotton. But it is not yet possible to assign with confidence all the types described to their correct botanical classifications.

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DEHYDRATION OF FOOD BY RADIO-FREQUENCY ENERGY

The Industrial Electronics Division of the Federal Telephone and Radio Corporation, co-operating with the Office of the Quartermaster-General of the United States Army, has developed a process of dehydrating food by means of radio-frequency energy. The process is described briefly by Vernon W. Sherman in an article (*Elec. Comm.*, 21, No. 2; 1943). The electronic dehydration method not only makes it possible to remove 99 per cent. of the mositure content but it also permits this high degree of dehydration after the vegetables have been compressed into a small block or briquette 6 in. × 3 in. × ¾ in. Compression of vegetables prior to total dehydration is an unprecedented procedure, other processes requiring exposure of as much of the vegetable surface as possible to facilitate evaporation. With all but one per cent. of this moisture removed, it is possible to pack all types of dehydrated vegetables in sealed containers and transport them to any part of the world without danger of decomposition. The length of time vegetables may be kept in good condition increases very greatly as the moisture content approaches one per cent. Evidence now indicates that vegetables dehydrated by the electronic method will not deteriorate over a period of one to two years even in hot, humid climates.

Vegetables reconstituted after electronic dehydration may be cooked and served in the same way as fresh vegetables. Reconstitution is accomplished by soaking the vegetables in water. They then return to their original colour and consistency and retain their normal taste and aroma. The vitamin content of electronically dehydrated vegetables is especially high, due apparently to the much shorter processing time. The exact method of dehydration cannot be disclosed at present. Briefly, however, 80 per cent. of the moisture is removed by conventional methods, leaving the vegetables pliable but without formation of 'case hardening'. The vegetables are then compressed into bricks and the remaining moisture is removed electronically, after which they are ready to be wrapped in paper, wax coated, packed and shipped. The whole procedure is well adapted to automatic straight line production. Laboratory results show that one pound of water may be removed electronically with less than one kWh. of energy, a figure which is economically good in comparison with other methods. In addition to vegetables, dried whole milk also has had its moisture content reduced electronically from two per cent. to one per cent.—(*Nature*, Vol. 152, No. 3863).

SUBSOIL FERTILITY OF ERODED VOLCANIC ASH IN ST. VINCENT, B.W.I.

Its Assessment by Chemical Analysis and Pot Tests

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(I) Introduction

The results of a preliminary investigation into the extent and significance of soil erosion in St. Vincent, and the relationship of erosion to the features of the main soil-types there represented, have already been described in this Journal (1)‡. It was concluded that the chief effect has been a wastage of *nitrogen* caused by loss of humic soil, particularly in arrowroot fields in which the surface layer is continuously being dragged downhill during the digging out of the rhizomes by hoeing in the reaping season. The fact was also stressed that available phosphate and potash, although somewhat more plentiful in the humic soil, are not necessarily deficient in the sub-soil exposed by erosion, because of the high content of fresh mineral grains in all parts of the profile. These observations adequately explain why applications of nitrogenous manures to lands worn out by sheet erosion and continued cultivation have been found in St. Vincent rapidly to renew their fertility. Thus, sulphate of ammonia, *applied alone* in manurial experiments, has increased the yield of arrowroot by 21 to 57 per cent.; of seed cotton, by 35 per cent. and of sugar-cane, by 20 per cent., in fields occupying badly-eroded hillslopes. Certain organic manures, mulches and cottonseed meal have also given large responses in similar circumstances.

In order further to test the fertility status of subsoils exposed by erosion, samples representative of the main agricultural soil-types of St. Vincent have been subjected to routine physical and chemical analysis and to pot tests with Sudan Grass as indicator plant. The results form the subject of this article.

(II) Description of the Soil-Types Investigated

Three kinds of subsoil materials were used in these investigations, namely (A) Recent Volcanic Ash, (B) Yellow Earth, and (C) Terras. These will be briefly described in turn.

(A) RECENT VOLCANIC ASH

This occurs in the northernmost part of St. Vincent where it comprises the finer material ejected from the Soufriere volcano during its latest eruption in 1902-1903. Historical records show that this volcano was also active in 1718 and 1812, and perhaps in 1814 and 1880. The older volcanoes further south, now comprising the Garu Mountains, have not erupted in historic times, but their ejecta are still comparatively fresh or only slightly weathered. A striking feature of the northern volcanic material is the absence of lava flows; the ejecta consist chiefly of small loose stones, "cinders", sand, "ash" and dust. Boulders over six inches in diameter are relatively rare in these volcanic fragmental materials. The colour of the Recent Ash is generally brownish-grey, dark grey or black. The larger fragments show the typical composite crystalline structure of andesite or basalt igneous rock, but the smaller pieces are frequently scoriaceous and pitted, or glassy and smooth. The smallest particles usually consist of individual mineral grains of white labradorite-felspar, green augite or hypersthene, and black magnetite. These are mostly vitrified so that presumably they are not so readily decomposed by weathering (which slowly liberates mineral nutrient components from them) as are normal crystal grains that have not been fused by heat.

The soil profile features of Recent Volcanic Ash are very variable, as would be expected from its intermittent manner of accumulation, and its frequent exposure to denudation between eruptions. They have already been described in detail in a special publication (2) in which the laboratory data for eleven 6-foot Volcanic Ash profiles are presented and discussed. The data clearly show the composite nature of the profiles and the occasional presence of buried organic layers covered over by more recent material (*See* Table I). The content of gravel (particles over 2 mm. diameter) ranges from 20 to 55 per cent.; that of coarse sand (2.0 to 0.2 mm.) from 60 to 85 per cent.; and that of fine silt and clay from 5 to 20 per cent. Colloidal clay is altogether absent. Organic matter fluctuates greatly in amount; it may be as high as 4 per cent. in the surface 6-ins. layer in some cultivated examples, but more generally it is less than 2 per cent. Consequently, total nitrogen content also fluctuates considerably. The available phosphate content of the surface 6-ins. layer averages 65 p.p.m., which is quite high, but that of the lower non-humic layers is much less. Available potash content lies around 125 p.p.m., which is only medium high, though it tends to be maintained at lower depths.

Apart from the crumbiness usually induced in the surface soil by the presence of humus, the Recent Volcanic Ash profile shows an incoherent single-grain structure throughout; rain-water easily penetrates and rapidly percolates downwards as in a heap of sand. Hence soil erosion is not conspicuous nor common, even on land

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‡ Numbers in brackets refer to references at the end of this article.

having a high degree of slope. During the heaviest rains, however, débris avalanches or mudflows may develop, or contour ridges may be breached by the banked-up water, but such occasions are rare. Drainage water, concentrated at a point, may start erosion gullies in Recent Ash deposits, as at German Gutter near Troumaka, but these again are rare and their initiation is easily preventable.

(B) YELLOW EARTH

This is the most widespread of the St. Vincent soil-types; it merges with the last in a transverse central belt running across the Island, but it is most widely developed in the south, especially in the windward coastal region and in the St. Andrews Mountains overlooking Kingstown. Except for a sporadic covering of Recent Ash, the material consists of fragmental volcanic ejecta that have been sufficiently weathered to have liberated appreciable amounts of limonitic iron oxide which confers a warm tawny-yellow colour on the soil. This gives a characteristic "fallow" appearance to the fields that are being prepared for planting.

The physical features of the Yellow Earth differ from those of the Recent Ash (*See* Table I), in that gravel is generally much less abundant, and greater amounts of silt and clay are present because of the formation of colloidal kaolin and limonite by the weathering of the felspathic and ferromagnesian components of the original parent material. Mineral decomposition has not been very profound, however, and most of the products may easily be washed off the mineral grains by rubbing in water, leaving their surfaces fresh and unstained as in Recent Ash. The presence of colloidal clay in the Yellow Earth gives appreciable cohesiveness to the component particles which helps to produce a crumb structure. Typically, insufficient clay substance is present to cement the grains firmly together, so that the material is still permeable, and downward drainage is free to great depth.

Organic matter content of Yellow Earth soil varies widely from about 4.5 to 0.5 per cent. in the top 6-ins. layer, depending on the degree of erosion. Humus usually penetrates deeply, producing a sepia-chocolate to nearly black surface layer up to 3 feet thick, sharply overlying the brownish-yellow subsoil (*See* Table I). The available phosphate content of the surface 6-ins. layer is exceptionally low, being generally less than 10 p.p.m., but available potash content is very high, namely, about 380 p.p.m., and appears to be sustained at a relatively high value in all the Yellow Earth profiles examined (2). Leaching has not been extensive, so that reaction values are generally above pH 6.0, and exchangeable calcium content is greater than 75 per cent. of the total replaceable bases.

Table I.—Comparison Between Typical Soil Profiles

RECENT ASH *versus* YELLOW EARTH

(Laboratory data for 6-foot profiles)

	(A) RECENT VOLCANIC ASH PROFILE							(B) YELLOW EARTH PROFILE (Uneroded)						
Lr. Dpth. (ins.)	Gravel Per cent.	Coarse Sand Per cent.	Fine Sand Per cent.	Silt + Clay Per cent.	pH	Org. Mat. Per cent.	C/N Ratio	Gravel Per cent.	Coarse Sand Per cent.	Fine Sand Per cent.	Silt + Clay Per cent.	pH	Org. Mat. Per cent.	C/N Ratio
3 ...	26	68	20	12	6.4	2.9	11.3	4	50	25	25	6.1	3.6	11.6
6 ...	37	75	16	9	6.4	1.1	10.6	7	51	24	25	6.1	3.1	11.1
12 ...	31	68	22	10	6.3	0.4	9.8	3	48	25	27	6.1	2.7	10.2
18 ...	32	62	18	20	6.1	1.1	10.7	2	46	25	29	6.0	2.0	10.0
24* ...	32	72	20	8	6.4	1.6	12.7	2	45	25	30	6.3	1.4	8.6
36 ...	35	82	7	11	6.3	1.9	11.3	0	43	23	34	6.4	0.9	9.6
48 ...	34	78	11	11	6.6	0.7	11.0	5	44	23	33	6.4	0.7	8.6
60 ...	27	68	17	15	6.7	0.5	9.5	0	36	25	39	6.3	0.4	9.5
72 ...	24	74	12	14	6.7	0.3	8.8	3	30	26	37	6.2	0.4	9.6
MEANS	30	73	14	13	6.5	—	—	2	43	24	33	6.2	—	—

NOTE: (1) The data for Recent Ash represent average values for 5 profiles at Mt. Bentinck sugar estate, situated at the south-east base of Mt. Soufriere. A buried soil is evident below 18 ins. depth.*

(2) The data for Yellow Earth are averages for 4 profiles at Carrieie, Lauders and Dorsetshire Hills arrowroot and cotton estates, windward coastal belt, elevation below 900 ft. The profiles are entire, i.e., not truncated by erosion; the humic layer averages 18 inches thick.

Erosion in typical Yellow Earth is similar to that of Recent Ash already described. According to Anderson and Flett, who studied geological conditions in St. Vincent after the 1902 eruptions (3), Yellow Earth, occupying the windward coastal belt, has moved bodily downhill during rainy periods when it became saturated with water, and the characteristic layered appearance, seen in the road cuttings, is thus readily explained. Such hillcreep or landslide is possibly dependent, however, on the existence of a more-or-less cemented subsoil which impedes downward percolation and thus encourages waterlogging and slipping.

(C) TERRAS

This is the name given in the British West Indies, somewhat indiscriminately, to more-or-less cemented old volcanic ash and agglomerate, and to much-decomposed lava (andesite or basalt) which are commonly used for road mending. The name is here provisionally applied to the indurated layer that develops at variable depth in Yellow Earth profiles as a result of the downward leaching and deposition of certain products of weathering, notably iron oxide, silica and alumino-silicates, which gradually cause a sealing-up of the subsoil. This may have profound effects on natural drainage and erosion, as has been indicated in the last section.

The Terras type of volcanic ash soil merges imperceptibly into the Yellow Earth type. When cementation is complete and the subsoil has set into a hard mass, resembling concrete, drainage impedence is complete, and an entirely different type of soil develops, in which water effects predominate. This hydromorphic soil (which has provisionally been termed *Shoal Soil*) is a distinctly clayey type, and a marked gley layer may form above the "shoal". Although not conspicuously developed in St. Vincent, Shoal Soil occurs characteristically in many of the other West Indies volcanic islands, notably Montserrat and Nevis.

(III) Results of the Laboratory Examination of Subsoil Samples used in the Pot-Tests

The actual subsoil samples examined in the laboratory by physical, chemical and biological methods will now be described.

(A) RECENT VOLCANIC ASH SUBSOIL

The sample was collected at the 4-foot depth from the 6-foot bank of the Rabaka Dry River near its estuary on the windward sea coast*. It consists of material ejected during the 1902-3 eruption of Soufriere. The dry material is pale brownish-grey in colour but almost black when wet. It is powdery and dense, and packs down tightly when shaken. The results of its partial physical and chemical analysis are given in Table II, from which it will be seen that the sample contains one-tenth of its weight of gravel. The fine soil contains about one-third coarse sand and one-half fine sand, the rest (nearly 20 per cent.) being silt and clay. The sample is thus rather fine grained for Soufriere ash. The material will scarcely bind when wetted, and readily falls down into single grain structure as it dries. The individual particles consist mostly of somewhat vitrified crystalline fragments of the characteristic minerals.

The chemical data (Table II) show that the sample is acid (pH 5.9), more so than all the profile samples of Recent Ash previously examined. The contents of organic matter and nitrogen are very small (0.33 and 0.03 per cent. respectively), with low carbon-nitrogen ratio (6.3).

Available phosphate is relatively high (84 p.p.m.), as is customary for this type when tested by the routine Truog method. (The content of *total* phosphate of this material is around 7,000 p.p.m., so that 1.2 per cent. of the whole is extractable by the Truog reagent, N/500 sulphuric acid). Available potash is fairly high (170 p.p.m.) as in other examples of Recent Ash. (The content of *total* potash is generally around 5,400 p.p.m., so that about 3 per cent. is extractable by N/2 acetic acid).

According to standards adopted in the College Chemistry Department, both available phosphate and available potash in this sample of St. Vincent Recent Volcanic Ash subsoil would be regarded as being more than adequate in amount to meet the needs of tropical crops.

*The sample of Recent Ash was kindly procured and sent, in 1936, by Mr. A. K. Briant, Agricultural Superintendent.

Table II.—Laboratory Data for Subsoil Samples Used in Pot Tests

	Coarse Sand Per cent.	Fine Sand Per cent.	Silt + Clay Per cent.	Index of Texture	Reaction Norm. pH	Reaction Exch. pH	Total O.M. Per cent.	Total N Per cent.	C/N Ratio	Avail. P_2O_5 p.p.m.	Avail. K_2O p.p.m.
(A) Fresh Ash	32*	42	15	3	5.9	5.0	0.33	0.030	6.3	84	170
(B) Yellow Earth ...	40	19	41	18	6.9	5.6	0.18	0.017	6.0	3	26
(C) Terras	40	25	35	7	7.1	5.9	0.18	0.021	4.9	5	79
LIMITS OF ADEQUACY for most tropical crops :—	...	...	...	...	...	...	...	...	...	50	120

* Gravel, 11 per cent.

(B) YELLOW EARTH SUBSOIL

The sample was collected between the 4 and 6-foot depths in a deep profile at Montrose Estate near Kingstown †. It is reddish-yellow in colour when dry, gritty to the touch, and packs tightly. Reference to Table II indicates that the material contains much less fine sand than the Recent Ash sample, though the proportion of coarse sand is about the same. Its content of silt and clay is relatively high (about 40 per cent.) because of the presence of appreciable amounts of colloidal clay, presumably mostly kaolin. The sticky point is 30 per cent., giving an index of texture, 18, denoting a sandy-loam. The material may be brought into a crumby condition by suitably working it with about 14 per cent. of its weight of water.

The material is nearly neutral in reaction, and the organic matter and nitrogen contents are very low, as is to be expected. The available phosphate content is extremely low (only 3 p.p.m.), and the available potash content is also very low (26 p.p.m.); both would be considered as quite inadequate for the growth of crop plants. (*Total* phosphate and *total* potash range around 1,500 and 2,000 p.p.m. respectively for Yellow Earth, so that only about 0.2 per cent. of the phosphate and 1.3 per cent. of the potash are available, which are both smaller proportions than for Recent Ash).

(C) TERRAS SUBSOIL

The sample of this material was collected at between the 2 to 4 feet depths from a main road cutting at Richmond Hill, overlooking the Kingstown Experiment Station. Its colour when dry is pale brownish-grey, with numerous darker brown patches, probably due to manganese oxide. The component assorted mineral grains are cemented by a rusty matrix rich in oxide of iron.

The sample of Terras subsoil does not differ much in its chief physical and chemical features from that of Yellow Earth (*See* Table II). It is somewhat coarser-grained and less colloidal. It contains about the same amounts of organic matter, nitrogen and available phosphate, but it has three times as much available potash. Both available phosphate and available potash are well below the limits of adequacy for tropical crops.

†This sample and the one of Terras subsoil were kindly procured and sent in July, 1941, by Mr. C. K. Robinson, the present Agricultural Superintendent of St. Vincent.

(IV) Results of Pot Tests

Owing to the smallness of the sample of Recent Volcanic Ash subsoil, full-scale pot tests by Mitscherlich's method could not be run on this material, though they were succesfully carried out on the subsoil samples of Yellow Earth and Terras. For the Recent Ash, ordinary flower-pot tests were run; these included an attempt to find whether an organic manure (raw humus) might prove beneficial when applied alone or in combination with artificial manures under controlled conditions, since this soil-type is characteristically deficient in colloidal matter.

(A) RECENT VOLCANIC ASH SUBSOIL

Experiment (1): The treatments, applied in one series of pot experiments in which only artificial manures were used, comprised triplicate cultures, as follows:—

(*a*) no manure (control),
(*b*) phosphate alone (0.44 g. P_2O_5 per pot, added as superphosphate),
(*c*) phosphate and nitrogen (0.40 g. N per pot, added as sulphate of ammonia),
(*d*) complete manure; nitrogen (0.40 g. N), phosphate (0.44 g. P_2O_5) and potash (0.60 g. K_2O, added as potassium sulphate).

Experiment (2): A second series of pot experiments, comprising triplicate cultures, included raw humus as well as artificial manures. The treatments were exactly the same as the last, except that 136 g. of raw humus were added to each culture.

The raw humus used was obtained from a natural peaty deposit that occupies a swampy hollow at San Juan cacao estate in the Montserrat District of Trinidad. It is a brownish-black, powdery, light, structureless material. Its chemical composition is given in Table III, in which it is compared with average oven-dried pen manure. The data show that the raw humus is much richer in nitrogen and phosphate than pen manure. Its reaction value is pH 5.1 (highly

Table III.—Composition of Organic Manure Used in Pot Tests with Recent Volcanic Ash Subsoil

	Total Organic Matter Per cent.	Total Ash Per cent.	Total Nitrogen Per cent.	C/N Ratio	Phosphate Total Per cent.	Phosphate Avail. p.p.m.	Potash Total Per cent.	Potash Avail. p.p.m.
Raw humus (air-dry)	60	17	2.95	12.0	0.48	168	0.21	832
Average pen manure (oven-dry)	68	32	1.90	20.0	0.11	—	0.21	—

acid), though it is capable of producing abundant nitrate (400 p.p.m.) when incubated at half saturation moisture content for two weeks. Used at the rate of 136 g. per pot, the raw humus dressing is equivalent to 4.0 g. total nitrogen, 0.65 g. total phosphate (P_2O_5), and 0.29 g. total potash (K_2O), as compared with the unit dressings of artificial manures, which were respectively, 0.40 g. nitrogen, 0.44 g. phosphate and 0.60 g. potash. Thus the raw humus may be represented by the formula, 10 N, 1.5 P, 0.5 K, where N, P, K, represent the unit dressings of the three main nutrient ingredients.

In the pot experiments with Recent Volcanic Ash subsoil, Sudan Grass was used as indicator plant in both series. The pots were ordinary unglazed earthenware flower-pots, each capable of holding 3½ lb. of the soil, or about two-fifths of the quantity which the standard Mitscherlich pot can hold. The flower-pots were dipped in molten paraffin wax before use so as to minimise loss of water by evaporation from the porous sides. Each pot was supplied with 40 Sudan Grass seeds, the seedlings being thinned out to 20 during the first three weeks of growth. The pots were watered each morning and evening for 14 weeks. The plants were harvested, dried in the oven, and weighed when 15 weeks old.

Observations during growth: First Series.

(*a*) The control (no manure) cultures grew poorly, and very few tillers were produced. The leaf-sheaths turned pink, then purple, and finally brown. The leaves turned brownish-green then yellow and soon shrivelled. Many plants died before 9 weeks old, and those alive at harvest time had formed no inflorescences.

(*b*) The phosphate-treated cultures to which no extra nitrogen had been added started off well, and a fair number of tillers were formed. The leaf-sheaths turned deep pink in colour, and the leaves pale green when the plants were 4 weeks old. Many of the leaves withered. At harvest, an average of two inflorescences per pot had developed, but none set seed.

(*c*), (*d*) The nitrogen *plus* phosphate cultures (NP), and the complete cultures (NPK) behaved similarly. All tillered well and the leaf-sheaths and leaves remained dark green throughout. At harvest, the first set had produced about 7 inflorescences per pot and the second about ten.

Second Series: (*a*) The cultures having raw humus alone tillered well, but from an early stage, the leaf-sheaths were coloured reddish-purple. The leaves were abnormally dark green but healthy in appearance. An average of 7 inflorescences per pot was produced, and all set seed

(*b*) The cultures with raw humus *plus* extra phosphate grew well from the start. Tillering was abundant, and the leaf-sheaths and leaves assumed a healthy green colour, though the sheaths at first were faintly pink. At harvest, an average of 9 inflorescences per pot had been produced, and all set seed.

(*c*), (*d*) The cultures having raw humus *plus* nitrogen and phosphate and raw humus *plus* complete artificial manures behaved alike; they were not much different from those receiving complete artificials with no humus. They tillered profusely and produced a bulkier crop than the raw humus *plus* phosphate treatment. An average of 8 inflorescences per pot was produced by the first set, and 4 by the second, and all set seed.

Insect damage: When 5 or 6 weeks old, the Sudan Grass plants in this experiment were unfortunately attacked by thrips (*Hercothrips insularis*) which caused considerable damage. Attempts at biological control, by introducing a hymenopterous parasite, failed, but a spray made of soft soap solution and nicotine, applied when the cultures were 8 weeks old, completely removed the thrips, and thereafter the growth of the plants improved.

The yields of dry matter obtained in this experiment are given in Table IV. The appearance of some representative cultures, one from each set, is shown in the photograph, Figure 1, taken when they were 8 weeks old.

Discussion: The following main deductions are based on the laboratory and greenhouse data for the Recent Volcanic Ash subsoil:—

(1) If no manure of any sort is applied to eroded Recent Volcanic Ash in which the subsoil has been exposed by the removal of fertile organic surface soil, very little crop may be expected.

(2) The addition of phosphate alone gives no better result, presumably because the material is deficient in nitrogen.

(3) The addition of both nitrogen and readily-available phosphate gives greatly increased yields, even when no potash is applied in addition.

(4) The effect of adding potash along with nitrogen and phosphate is to increase the yield only slightly and possibly not significantly, judging by the range of pot yields.

(5) The application of organic manure (raw humus), containing abundant nitrogen,* does not appreciably increase the yield,

*NOTE: In these experiments on Recent Volcanic Ash, a serious omission was a set of cultures receiving inorganic nitrogen alone (say, sulphate of ammonia). In certain preliminary experiments, however, conducted in 1940 by A. S. Harper (Diploma Student at the College), a series of pots containing the same St. Vincent Recent Volcanic Ash subsoil was treated with increasing doses of sulphate of ammonia, without addition of phosphate or potash. These gave practically no yields of Sudan Grass at all. In the presence of superphosphate, sulphate of ammonia gave greatly increased yields (as in our experiment), thus substantiating the finding that Recent Volcanic Ash subsoil is very deficient in *available* phosphate. Sulphate of potash, as also in our experiments, conferred no additional benefit, thus providing proof that the soil contains an adequate amount of easily-available potash.

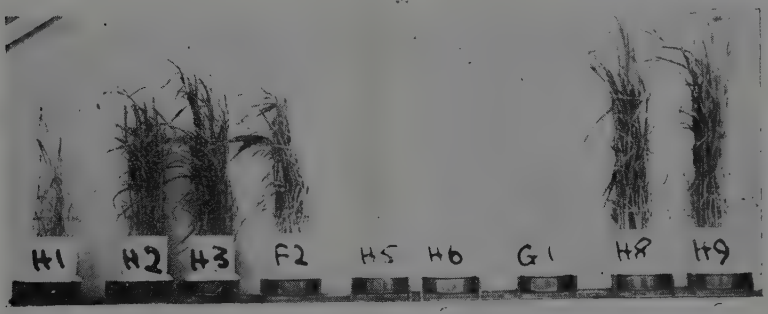
Figure 1.—Recent Volcanic Ash Subsoil

Representative flower-pot cultures ; 8 weeks old

No. 1 (M1), No manure :
No. 3 (M9), N,P :
No. 5 (N1), raw humus alone :
No. 7 (N7), raw humus, N,P :
No. 2 (M5), P alone
No. 4 (M10), N,P,K.
No. 6 (N4), raw humus, P
No. 8 (N11), raw humus, N,P,K.

Figure 2.—Yellow Earth Subsoil

Representative Mitscherlich pot cultures : 8 weeks old.



No. 1 (H1), P,K :
No. 4 (F2), N, 3P :
No. 7 (G1), N, 2K :
Nos. 2, 3 (H2, H3), N,P
Nos. 5, 6 (H5, H6), N,K
Nos. 8, 9 (H8, H9), N,P,K.

Figure 3.—Terras Subsoil

Representative Mitscherlich pot cultures : 10 weeks old

No. 1 (L1c), P,K :
No. 3 (J2), N,3P :
No. 5 (K1), N,2K :
No. 2 (L3), N,P
No. 4 (L7), N,K
No. 6 (L10), N,P,K.

Table IV.—Results for Recent Volcanic Ash

FIRST SERIES : *Artificial manures alone*

	Culture	Average height (cm.)	Yield (g.)	Mean Yield (g.)	Yield ; per cent. highest
M 1			0.26		
M 2	Control (no manure)	12	0.27	0.28	0.6
M 3			0.31		
M 4			5.8		
M 5	P (No N, no K)	68	2.5	3.9	9.1
M 6			3.5		
M 7			20.5		
M 8	NP (No K)	174	35.0	30.1	70.2
M 9			34.8		
M 10			31.7		
M 11	NPK (complete)	170	33.2	31.1	72.5
M 12			28.5		
SECOND SERIES : *Raw humus plus artificial manures*					
N 1			11.5		
N 2	Raw humus alone	118	8.9	9.6	22.4
N 3			8.6		
N 4			26.4		
N 5	Humus and P	162	34.9	34.3	80.0
N 6			41.6		
N 7			41.6		
N 8	Humus and NP	166	51.7	42.9	100.0
N 9			35.3		
N 10			37.5		
N 11	Humus and NPK	172	39.3	36.5	85.1
N 12			32.7		

NOTE :—Raw humus=10N, 1.5P, 0.5K

even though the manure also contains a fair amount of total phosphate and some potash.

(6) The addition of readily available phosphate (in the form of superphosphate), together with raw humus, gives greatly increased yields. (This suggests that the phosphate component of the raw humus is relatively unavailable, otherwise this organic manure alone would have given a large response).

(7) The addition of more nitrogen to the last treatment gives only slightly (and probably insignificantly) greater response than the raw humus alone.

(8) The addition of readily-available potash seems to cause a depression in yield.

Conclusions : Recent Volcanic Ash subsoil, *though apparently containing a large amount of available phosphate* according to a widely-applicable standard chemical test, nevertheless completely fails to satisfy the needs of Sudan Grass, which is known to be particularly sensitive to phosphate shortage.

In this respect therefore, recent Volcanic Ash of the kind occurring in St. Vincent behaves *abnormally* toward the specific chemical test employed, namely, the Truog test, in which N/500 sulphuric acid is used as extracting agent. Presumably, in Volcanic Ash, the phosphate mineral present (believed to be *apatite*) occurs in an especially resistant or unavailable form, so that plants cannot utilise it. Perhaps incipient fusion might render the mineral less available to the plant. Consequently, when manuring unaltered Volcanic Ash, some easily-available phosphate manure must be applied along with nitrogenous manure in order to obtain satisfactory crops. The most suitable form is doubtless superphosphate or similar soluble phosphatic manure, though perhaps certain organic manures (other than raw humus), including filter-press mud (which is known to be rich in calcium phosphate), might serve equally well, and these deserve trial by means of pot tests and field manurial experiments in St. Vincent.

The pot experiments afford no evidence that the value of the particular organic manure employed in our experiments depends on any factor other than the nitrogen it contains.

(II) YELLOW EARTH SUBSOIL

This material was subjected to pot tests by the Mitscherlich method, in which special enamelled iron cylindrical vessels, each containing about 9 lb. of subsoil, were used. No dilution with inert quartz sand was deemed necessary, since the material was sufficiently permeable. The objects of the test were threefold, namely:—

(1) to determine the effect of increasing doses of nitrogen in the presence of excess of phosphate,

(2) to determine the effect of increasing doses of nitrogen in the presence of excess of potash,

(3) to determine the nutrient status of the material by the conventional Mitscherlich procedure.

Sudan Grass was used as indicator plant.

Experiment (1): *Phosphate effect*

The treatments, in duplicate, were:—

F1, F2; N, 3P
F3, F4; 2N, 3P
F5, F6; 3N, 3P

where N=1.0 g. N per pot, as sulphate of ammonia,

P=1.1 g. P_2O_5 per pot, as superphosphate.

Observations during growth: In each of the cultures, the growth of Sudan Grass was healthy and vigorous, and little difference could be discerned between them. All tillered well and early, and at harvest time (14 weeks), all looked alike. Only two inflorescences were produced. One of the cultures (F2) appears in the photograph, Figure 2.

The yields of dry matter are given in Table V.

Table V.—Yield Results: Yellow Earth: Nitrogen *plus* Phosphate Series

Culture	Average height (cm.)	Yield (g.)	Mean Yield (g.)	Yield; per cent. highest
F 1, F 2 — N, 3P	106	36.3, 51.2	43.8	55.8
F 3, F 4 — 2N, 3P	103	47.4, 46.9	47.2	60.1
F 5, F 6 — 3N, 3P	105	59.8, 60.1	60.0	76.3

Experiment (2): *Potash effect*

The treatments, in duplicate, were:

G1, G2; N, 2K
G3, G4; 2N, 2K
G5, G6; 3N, 2K

where, N=1.0 g. N per pot, as sulphate of ammonia,

K=1.5 g. K_2O per pot, as sulphate of potash.

Observations during growth: When only two weeks old, the cultures began to show signs of poor health. The leaf-sheaths and leaves were abnormally deep green in colour, but later turned purple, then brown, and finally withered. No tillering occurred. No further growth took place after 3 weeks. At 8 weeks, all the plants were dead except about 7 out of the 35 per pot that started seedling growth. No inflorescences were formed. One of the cultures (G1) is shown in the photograph, Figure 2.

The yields of dry matter obtained are given in Table VI.

Table VI.—Yield Results: Yellow Earth: Nitrogen *plus* Potash Series

Culture	Average height (cm.)	Yield (g.)	Mean Yield (g.)	Yield; per cent. highest
G1, G2 — N, 2K	—	0.41, 0.38	0.40	0.50
G3, G4 — 3N, 2K	—	0.79, 0.39	0.59	0.75
G5, G6 — 3N, 2K	—	0.37, 0.52	0.45	0.57

Experiment (3): *General nutrient status* (*Mitscherlich test*)

The standard Mitscherlich treatments were:—

H1;	No nitrogen	(P,K)	where N,P,K= as before
H2, H3	No potash	(N,P)	
H5, H6	No phosphate	(N,K)	
H8, H9	Complete	(N,P,K)	

Observations during growth: No nitrogen treatment: At first the cultures grew well and seemed to be healthy. Each plant produced one or two tillers. Growth diminished sharply, however, after 5 weeks. The leaves turned yellow, then brown, and soon withered. The leaf-sheaths were pink. Most of the plants died at 8 weeks, and nearly all were dead at 13 weeks. Only one stem formed an inflorescence.

No potash treatment: The behaviour of these cultures was very similar to that of the "F" cultures in the last experiment. Growth was regular up to harvest. Tillering was free, and many of the stems produced inflorescences.

No phosphate treatment: The cultures resembled those of the "G" series in the last experiment. Only 7 plants were alive out of a total of 70 after 8 weeks, and only 4 survived to 9 weeks.

Complete treatment: These cultures all grew well and tillered early. The plants were the tallest and bulkiest of all, and were the earliest to flower. Inflorescences appeared at 9 weeks, and most stems (70 per cent.) produced them.

The yield data are given in Table VII.

The appearance of each of the seven cultures is shown in Figure 2.

Table VII.—Yield Results: Yellow Earth: Mitscherlich Test.

Culture	Average height (cm.)	Yield (g.)	Mean Yield (g.)	Yield; per cent. highest
H1 P,K (No N)	98	5.6	5.6	7.1
H2, H3 N,P (No K)	146	26.6, 34.9	30.8	39.2
H5, H6 N,K (No P)	—	0.50, 0.55	0.53	0.68
H8, H9 N,P,K (complete)	201	68.4, 88.6	78.5	100.0

Discussion: (1) It is evident from the results of these three experiments that the Yellow Earth subsoil initially contained a sufficient amount of nitrogen to enable Sudan Grass to start growing when adequate amounts of phosphate and potash were added. (Culture H1, Expt. (3)). The growth is seriously restricted, however, since the initial supply of nitrogen is soon exhausted. The yield in the absence of extra nitrogen was only about 7 per cent. of the maximum.

(2) In the presence of increasing doses of extra nitrogen, growth is greatly enhanced, *provided* an adequate amount of phosphate is also present (Expt. (1)). The largest dose of added nitrogen (3N), gave an appreciably higher yield than either the smallest dose (1N) or the intermediate dose (2N), but even then, the maximum was not attained (NPK=100; Expt. (3)), so that evidently potash now became the limiting factor.

(3) Potash gives no response when extra nitrogen is also added in the absence of phosphate (Expt. (2)). In the presence of both nitrogen and phosphate, however, readily-available potash produces appreciable further growth (Expt. (3)), for the complete manure gives the largest yield of all. The yield in the *absence* of extra potash (Expt. (1)) was only about three-quarters of the maximum (obtained in Expt. (3)).

Conclusions: It will be remembered that, by chemical tests, the St. Vincent Yellow Earth subsoil seemed to be markedly deficient in all three main nutrients, nitrogen, phosphate and potash. The chemical evidence is fully supported by the results of the pot tests, which show that, apart from nitrogen, phosphate is the nutrient whose addition in easily-available form produces greatest yield response in Sudan Grass. Only when phosphate is present in sufficient quantity is potash manure capable of conferring benefit on this soil-type.

NOTE:—Owing to an accident, some of the harvested plant material from the last experiment was scorched while being dried in the oven, so that the yields had to be derived from ash contents. This precluded the application of the Mitscherlich calculations for assessing the nutrient requirements of this soil.

(III) TERRAS SUBSOIL

This material was examined by pot-test methods in exactly the same way as the Yellow Earth subsoil last considered.

Experiment (1): *Phosphate effect*

Yield results are given in Table VIII, and the appearance of a typical culture (J2) is shown in Figure 3. Growth behaviour was exactly similar to that of the corresponding cultures of Yellow Earth subsoil.

Table VIII.—Yield Results: Terras: Nitrogen *plus* Phosphate Series.

Culture	Average height (cm.)	Yield (g.)	Mean Yield (g.)	Yield: per cent. highest
J1, J2, J2A N, 3P	152	49.7, 58.1, 64.4	57.4	56.9
J3, J4, J4A 2N, 3P	143	72.9, 68.2, 75.8	72.3	71.7
J5, J6, J6A 3N, 3P	139	78.8, 76.5, 74.2	76.5	75.9

Experiment (2): *Potash effect*

Yield results are presented in Table IX. The appearance of a typical culture (K1) is shown in Figure 3. The growth was insignificant, though the yields were somewhat larger than those obtained in the analogous experiment with Yellow Earth subsoil.

Experiment (3): *General nutrient status (Mitscherlich test)*

Here again, the behaviour of the cultures and the yield data for the Terras subsoil were very similar to those given by the Yellow Earth subsoil, except that the no potash cultures (L) gave significantly greater yields than the corresponding cultures of Yellow Earth subsoil. Yield results are given in Table X, and four of the cultures (L1c, L3, L7, L10) are shown in Figure 3.

Table IX.—Yield Results: Terras: Nitrogen *plus* Potash Series

Culture	Average height (cm.)	Yield (g.)	Mean Yield (g.)	Yield; per cent. highest
K1, K2 N, 2K	—	0.48, 0.37	0.43	0.43
K3, K4 2N, 2K	—	1.27, 0.85	1.06	1.05
K5, K6 3N, 2K	—	0.96, 0.57	0.77	0.76

Table X.—Yield Results: Terras: Mitscherlich Test

Culture	Average height (cm.)	Yield (g.)	Mean Yield (g.)	Yield; per cent. highest
L 1a, L 1b, L 1c P,K (No N)	74	8.6, 5.3, 7.7	7.2	7.2
L 2, L 3, L 4 N,P (No K)	166	81.0, 75.7, 62.0	72.9	72.4
L 5, L 6, L 7 N, K (No P)	—	0.97, 0.45, 0.75	0.73	0.73
L 8, L 9, L 10 N,P,K (complete)	209	103.7, 106.0, 92.8	100.8	100.0

Discussion: (1) It is evident from the results of the last three experiments that the nutrient status of Terras subsoil is very similar to that of Yellow Earth subsoil, except that it is richer in available potash.

(2) Whereas Yellow Earth subsoil to which nitrogen and phosphate manures were added in the straight Mitscherlich test gave less than 40 per cent. of the maximum yield, Terras subsoil to which nitrogen and phosphate had been added gave over 72 per cent. of the maximum. The differences between the yields of the "lacking potash" cultures in the Experiment (1) (i.e. the 3N, 3P treatments) were also large, the actual plant yields being considerably greater for the Terras culture, namely 76.5 g., as against 60 g. for the Yellow Earth culture.

Conclusions: On the basis of chemical tests, the Terras subsoil sample showed a great deficiency in total nitrogen and in available phosphate, but its available potash content was appreciably greater than that of the Yellow Earth subsoil sample (namely 79 p.p.m. as against 26 p.p.m.), though the amount present could not be regarded as adequate for the growth of most crops. This difference in potash status between the two soil-types is also revealed by the results of the pot tests which thus substantiate the results of the chemical analysis.

Nutrient deficiencies derived from Mitscherlich's formulae.

The application of Mitscherlich's method of calculation (4) to the pot test data for the Terras subsoil sample gave the results presented in Table XI.

From these results it will be seen that, although the total *nitrogen* content of the Terras subsoil is very small, namely, 210 p.p.m., the Mitscherlich pot tests proves that only 7 p.p.m. of this (one-thirtieth) is available to the indicator plant. In order to produce large crops, more than a ton an acre of sulphate of ammonia would be required by this soil according to Mitscherlich's standards.

For *phosphate*, the pot test, as well as the chemical test, show insignificant amounts of available phosphate, and dressings of nearly half-a-ton of superphosphate would be recommended by Mitscherlich for this soil.

For *potash*, both tests show also inadequate amounts. A dressing of over 2 cwt. per acre of sulphate of potash would be suggested on the basis of the pot test.

Table XI.—Terras Subsoil: Nutrient Deficiencies

(Results of calculations based on Mitscherlich's formulae)

Nutrient	Calculated from Mitscherlich data (cwt.ac.)	Expressed as p.p.m. top 6-ins. (p.p.m.)	Determined by chemical analysis (p.p.m.)	Manurial Requirements Calculated from Mitscherlich data: Nutrients (cwt.ac.)	Manurial Requirements Calculated from Mitscherlich data: Standard manures (cwt.ac.)
Nitrogen (N) ...	0.131	7	210	4.67	S/A 23.4
Phosphate (P_2O_5) ...	0.004	0.2	5	1.75	Super 9.7
Potash (K_2O) ...	0.480	27	79	1.12	S/Pot 2.2

(V) Suggestions and Recommendations

(1) The results of these investigations indicate that eroded lands in St. Vincent may be renovated, at least temporarily, by the proper use of inorganic nitrogenous and soluble phosphatic manures, but that best results can be expected only when these two are used in combination. The fundamental need of readily-available phosphate, in which the parent materials of the three chief volcanic ash soil-types of St. Vincent are peculiarly deficieny, cannot be overstressed.

(2) The value of potash manures is complementary, and best results therewith can be expected only when the nitrogen and phosphate status of the eroded soils has first been raised to an adequate level.

(3) The nitrogen status of eroded St. Vincent soils might, in practice, be most economically improved by means of suitable *leguminous cover-crop plants*, systematically included in soil conservation schemes, but these should be liberally manured with soluble phosphatic manure, otherwise their growth and nitrogen assimilation may be unsatisfactory for the purpose in view. Potash manure, in cases where it is likely to prove beneficial, might be applied in addition.

(4) Before attempting to put these recommendations into effect on a large scale, extensive field experiments with the principal crops of St. Vincent (arrowroot, cotton, sugar-cane, ground provisions), should first be carried out on the chief soil-types occurring in different agricultural districts.

(VI) Summary

(1) This article describes the results of laboratory analysis and pot tests (with Sudan Grass) applied to samples of non-humic subsoil representative of that which is exposed on badly eroded lands in St. Vincent, B.W.I.

(2) Three chief soil-types were considered, namely, (A) Recent Volcanic Ash, (B) Yellow Earth, and (C) Terras (or cemented ash), whose parent rocks are andesite or basalt.

(3) Apart from an obvious shortage of nitrogen, the three subsoils were found to be very deficient in *available phosphate*, although the Recent Ash showed a high phosphate content by the Truog test.

(4) *Available potash* also proved to be inadequate, except perhaps in Recent Ash, but potash manure conferred no benefit in any case unless accompanied by soluble phosphate manure. The potash status of Terras subsoil was somewhat higher than that of Yellow Earth subsoil.

(5) It is accordingly recommended that appropriate combinations of nitrogenous and phosphatic manures be tested in field experiments for renovating eroded lands in St. Vincent, and that the additional benefit which potash manures may confer in some cases be also further investigated.

(6) The employment of suitable leguminous cover-crops for providing the necessary nitrogen by fixation from the atmosphere, grown with the aid of liberal dressings of soluble phosphate manure, is also suggested for extended field trial.

(VII) References

(1) Soil Erosion in St. Vincent, B.W.I., by F. Hardy, *Trop. Agriculture*, 1939, XVI, pp. 58-65.

(2) The Agricultural Soils of St. Vincent (Pt. VIII of Studies in West Indian Soils), by F. Hardy, C. K. Robinson and G. Rodrigues, *I.C.T.A.*, 1934, pp. 44.

(3) A Preliminary Report on the Recent Eruptions of the Soufrière in St. Vincent in 1902, by T. Anderson and J. S. Flett, *Proc. Roy. Soc., London*, 1902, LXX, pp. 353-548.

(4) Investigations of the Mitscherlich Method in Trinidad, by B. de L. Inniss and F. Hardy, *Trop. Agriculture*, 1936, XIII, pp. 292-298.

BARE ROOT PLANTING OF CITRUS

Since packing material and transport facilities have almost vanished in N. Africa, the planting of young citrus with bare roots instead of the customary ball of soil has been undertaken with success when certain precautions have been observed. The operation should preferably take place at the end of winter, while dormancy still persists if on heavy wet soils, and in autumn on light soils which warm up easily. Delay between lifting and replanting should be reduced to a minimum. The trees are headed back some days before removal, leaving about a quarter of the original growth in the form of ripened wood well furnished with buds, the presence of old leaves being immaterial. The larger pruning cuts should be stopped with mastic. The trees should not be watered before lifting, in fact a slight wilting is an advantage. The most important operation of all is that the roots and the lower part of the stem should be at once dipped in a semi-liquid mixture of mud and fresh cow dung. They are then shaded and packed in bundles for removal to the site. On reaching their new quarters they must not be distributed to their respective holes in advance of planting but kept under cover till needed. A good plan is to stand them in a barrel or deep box on a handcart and let them accompany the planters. Even if the weather is wet an immediate watering is required to assist in packing the earth round the roots and the trunks must be at once whitewashed. Plants so treated are often superior in vigour and yield to those planted with the orthodox ball of soil attached. (*Horticultural Abstracts*, XIII, No. 3, p. 123.)

CHEMICAL NOTES

(Compiled by the College Department of Chemistry and Soil Science)

Phosphate Experiments on Coconuts

According to the 1941 Annual Report of the Coconut Research Scheme studies on the available phosphoric acid in coconut plots have been made for five years since the first sampling. In contrast to a marked decrease of available phosphate in plots to which no phosphate has been applied for five years, the plots manured with phosphate nearly trebled the amount of available phosphate. Total phosphate (soluble in concentrated hydrochloric acid) of samples taken between rows remained constant in all samples, except on gravelly soil, but total phosphate in phosphate-manured circles varied according to the amount of available phosphate.

* * *

Determination of Available Moisture in Soil

Probably the most promising approach to the problem of "available" moisture, as well as to many other soil-water relationships, is that of the suction force of soil now generally expressed in pF units. From the physical point of view it has the advantage of being based on fundamental values (differences in free energy) which seem capable of close alignment with the mechanical conditions governing the intake of water by plants. Thus, C. M. Woodruff (1) concludes that available water is that which is held by the soil within the pF range 3.0-4.1. At higher pF ranges the plant appears to be completely unable to withdraw moisture from the soil. Similar observations have been recorded by other workers, notably those at Rothamsted. The technique of the determination is in process of careful examination and tensiometers of various forms are being described. A recent paper by L. A. Richards (2) gives details of the construction of a servicable tensiometer together with useful notes on the setting up and checking of the instrument for field measurements of pF. Such an instrument does not operate successfully over the whole of the moisture range available to plants but provides a mass of valuable information concerning the water status of soils. The systematic use of pF measurements in soil investigations must await further examination both in technique and in co-ordination with soil and plant characteristics but there seems every prospect that this may afford an effective common measure in the elucidation of many soil-water problems and in the linking up of the somewhat diverse approaches to these problems. —(Extract from *Annual Reports of the Society of Chemical Industry on the Progress of Applied Chemistry*—Vol. XXVII).

1. *Proc. Soil Sci. Soc. Amer.*, 1941, **5**, 36; B., 1942, III, 124.
2. *Soil Sci.*, 1942, **53**, 241; B., 1942, III, 228.

Handling Avocado Soils

The ideal soil for avocados is porous and well aerated containing a large proportion of sand and gravel. Avocado roots are very sensitive to a restricted air supply. Trees on soils with a comparatively loose upper stratum but a compact sub-soil will show dieback after a few years and any lack of drainage is fatal. Cultivation should be shallow on account of the great number of surface feeding roots. A permanent cover crop should not be grown on any soil that is not easily permeated by water. (*Horticultural Abstracts*, XIII, No. 3, p. 126.)

* * *

Effect of Burning Rhode Grass in Soil

In Queensland it has been noticed that where Rhodes grass is closely grazed or burnt off before ploughing-under a three-year-old sod on fertile clay loam, the physical condition of the surface soil in the second or third season of cultivation may not be as permeable—particularly on slopes—as is desirable. An experiment to compare ploughing under of Rhodes grass in February and in June included observations on the consumption of soil moisture to a depth of 18 inches by Rhodes grass. Greater permeability of the June (winter) ploughed area was in evidence throughout the season during each rain group experienced. Nitrate content of the soil was determined fortnightly for each 6-inch depth: the growth of plants throughout the season clearly reflected the nitrate content of the top 18 inches of soil at each date of ploughing. —(*Empire Cotton Growing Corporation Progress Reports from Experiment Stations* 1941-42.)

* * *

Potash Content of Coconut Husks

The contention that the potash contained in the husk of the seedling coconut is held in such a way as to be wholly available to the growing plants by way of the first roots has been shown to be inaccurate: the greater portion of the potash in the husk is rapidly leached out into the soil. The observational results on this point have an important bearing upon nursery management in so far as they indicate the necessity for manuring nurseries with potash when they are on a free-draining sandy soil.—(*Soils and Fertilizers*, VI, No. 3.)

* * *

Growing of Fodder Grass between Coconuts

The growing of fodder grass between coconut palms depressed yields of copra by 17 per cent.; when fodder was not grown between palms, manuring with a heavy dose of sulphate of ammonia reduced the yield of copra, but applying the same dressing to fodder grown between palms increased the yield of copra.—(*Soils and Fertilizers*, VI, No. 3.)